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**EFFECTS OF ENVIRONMENTAL TEMPERATURE ON
SELECTED BLOOD SHIPPING CONTAINERS**

(Interim Report)

by

**Dailey W. McPeak
LTC Charles E. Shields, MC
and
LTC Frank R. Camp, Jr., MSC**

**Blood Transfusion Division
US ARMY MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky 40121**

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ABSTRACT

EFFECTS OF ENVIRONMENTAL TEMPERATURE ON SELECTED BLOOD SHIPPING CONTAINERS

OBJECTIVE

Evaluation of the protection afforded blood when packed in selected blood shipping containers and subjected to various environmental temperatures.

METHODS AND PROCEDURES

Loaded blood shipping containers were preconditioned to a temperature of 4°C. A Yellow Springs Model 47 eleven-point scanning telethermometer with thermistor probes was used to measure the temperature of the test units. The thermistor probes were placed inside the bag near the middle. Corner units, being the most exposed, were the monitoring units in these studies since they responded faster to external environmental changes than did the center units. Temperature measurements were made simultaneously. Ice was weighed at the beginning of the experiment and again when the temperature in the corner units reached 10°C. The climatic room was controlled within $\pm 1.0^\circ\text{C}$ at selected temperatures.

RESULTS AND CONCLUSION

The relationship between temperature holding capacity of each type of box versus time shows that the standard cardboard box with insulating plastic insert is three times more effective than the uninsulated standard container. Also, the presence of unmelted ice within the shipping container cannot be considered a reliable sign of safe blood temperature. Thus, it would be more practical and safer to measure the temperature of the blood in the box than to rely on the amount of unmelted ice as a guide to blood usability.

EFFECTS OF ENVIRONMENTAL TEMPERATURE ON SELECTED BLOOD SHIPPING CONTAINERS

INTRODUCTION

The therapeutic value of blood dates back to antiquity, but transfusion, in the modern sense of the term, became a reality only when problems with blood coagulation, agglutination, hemolysis and infections following transfusion could be overcome. During World War I, a specific blood transfusion technique was developed through the combined efforts of surgeons from Great Britain and the United States.

The general practice was to collect the blood within a 6 to 8 mile area, haul it by ambulance over rough roads for storage in an icebox, to be used within 10 to 14 days. In contrast, present-day blood banks supply blood, with a two- to threefold increase in shelf life, to American and Allied armies many thousand miles away from the collecting station. Yet, two major problems common to both blood banking periods still remain--that of mechanical transport and maintenance of satisfactory storage temperature.

For more than two decades, the standard acceptable maximum temperature that blood may reach and still be considered of good quality is 10°C. Work by Gibson, Parpart and others, immediately following World War II, provided evidence supporting this as a safe temperature (1, 2). There are several reports indicating the need to maintain blood at low temperatures. Hughes-Jones, in 1958, measured posttransfusion survival of erythrocytes stored at temperatures fluctuating from 4 to 10°C and found the survival reduced by 11% (6). At temperatures above 15°C, Gibson reported markedly accelerated deterioration of blood (2).

Concern for proper mechanical transport and maintenance of a safe temperature of the blood, combined with the misconception that plasma was an effective substitute for blood, initially delayed the development of the whole blood bank concept (3, 4). Significant progress began, however, in 1942, following the Allied invasion of North Africa. During this invasion, the problems of blood therapy were sharply brought to light when the high rate of casualties demonstrated the inadequacy of plasma as a whole blood replacement. The British were the first to recognize this and aided in developing an organized blood bank program for the Allied Forces involving transoceanic blood exchange between the United States and European nations.

Various blood shipping containers have been designed to protect the blood in transit. One of the first containers was made of plywood and built by a field medical unit. The lid was attached to the box with common door hinges. Salvaged blankets were used as cushioning and insulation. Another shipper was the Church container which provided ample protection and refrigeration for the blood and was used primarily in rail shipments. During World War II, the marmite can was also used extensively. The can was normally packed with 10 bottles of blood, 10 recipient sets, and 10 pounds of wet ice. This system of refrigeration usually provided storage at 4 to 4.5°C for 40 hours at ambient temperatures of 18 to 28°C. However, the common disadvantages of many of these containers, particularly the marmite can, were high cost, excessive weight, and lack of durability.

As various shipping containers were designed, new transportation methods were developed, including the use of air delivery by cargo chutes (Fig. 1). Recent advent of the helicopter as a medical transportation tool has reduced the necessity of parachute supply. Other methods are still being devised to meet unusual situations in which terrain, environmental conditions, and enemy forces may prevent the landing of a helicopter and the deliverance of blood and blood products by usual over-land transportation, including parachutes. New types of cushioning material, particularly plastic sheets containing trapped air bubbles,

were developed that provided sufficient protection to permit air delivery of whole blood or frozen plasma by free fall drop without the use of parachutes. Furthermore, the technique can be modified for use with fixed wing aircraft, as well as helicopters, and has been favored by pilots in Vietnam (5).

The other major factor remains—that of temperature. Maintaining blood within a fairly narrow temperature range is generally a minor problem except when the blood is being shipped. At the time of shipment, the only practical portable refrigerant, wet ice, must be added. Additional ice may be required during the trip if either the outside temperature is excessively high or the time in transit is long.

In current blood banking operations, a shipping box is normally packed with 15 units of whole blood and 14 pounds of wet ice. Though the ice is normally the refrigerant, it has often been used as a monitor of satisfactory shipping temperatures. Finding ice still present when the shipment was received, one would expect the temperature to have been maintained at 10°C or lower and the blood still be usable. The purpose of this report is to present observations on the amount of ice present and the actual temperature of the blood units within selected blood shipping containers at various environmental temperatures.

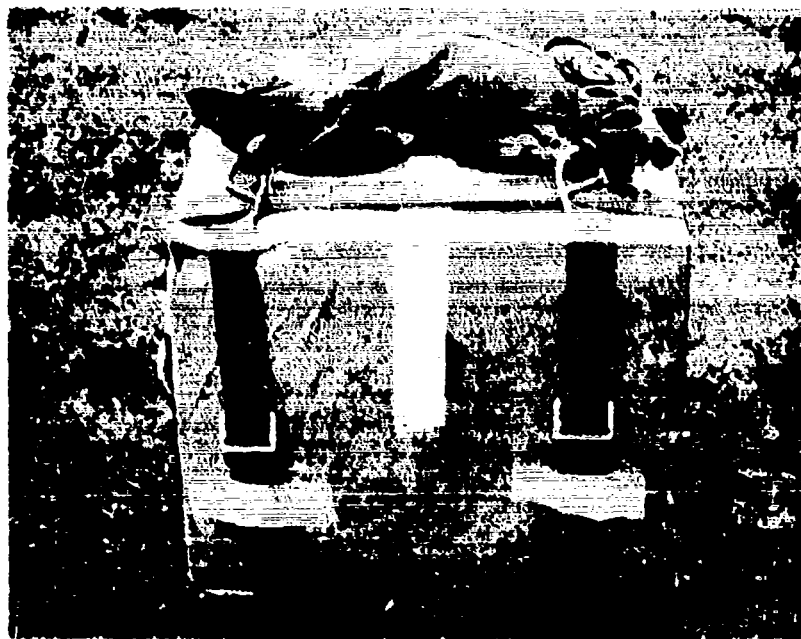


Fig. 1. Cargo chute.

METHODS AND MATERIALS

The method for measuring the temperature of the individual units was examined first. Three thermistor probes were used. Two were placed inside the bag with one near the top and the other near the bottom. The third was placed outside the bag near its center. Simultaneous measurements from all three were obtained and values over time are shown in Figure 2. The differences between the temperatures at the

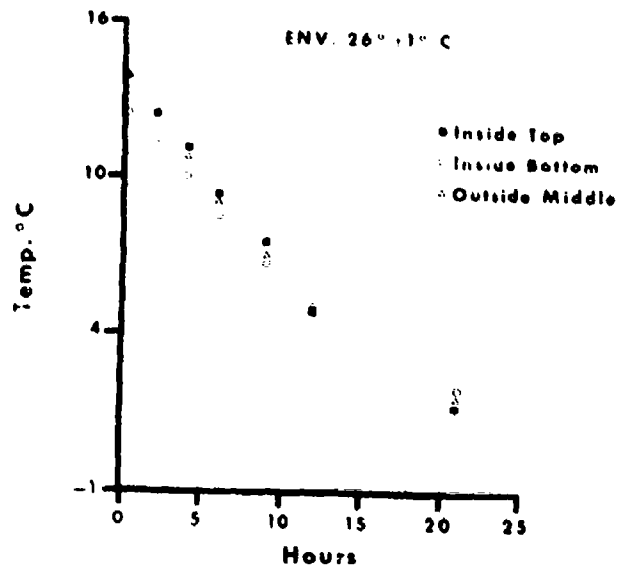


Fig. 2. Placement of three probes on unit.

three positions were negligible and subsequent monitoring was done with one probe inside the bag near the middle. Corner units, being the most exposed, responded faster to external environmental changes than did the center units, as shown in Figure 3, and thus were chosen as the logical units to monitor.

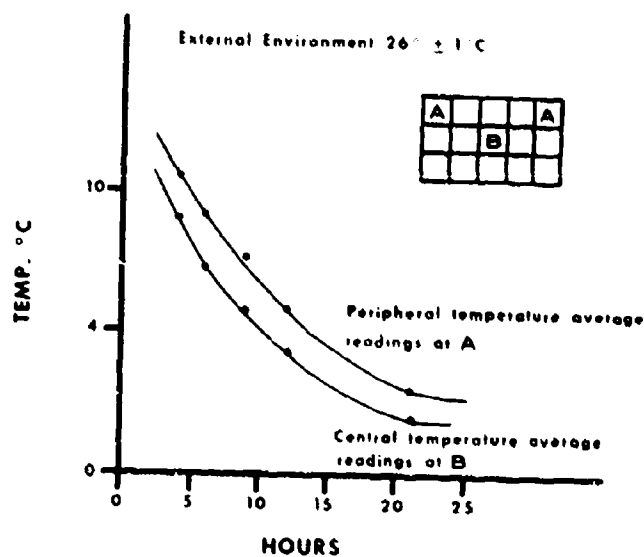


Fig. 3. Temperature of center units versus corner units.

The three boxes studied are shown in Figure 4. In the center is the plastic liner to be inserted. On one side is the standard box and on the other is the same box with plastic cushioning material (Air Cap). Measurements were made periodically from the time the refrigerated units were placed in the pre-cooled boxes until the experiment was terminated on the third or fourth day. The temperature results were graphed and the time from the start until the units reached 10°C was considered critical. In addition, the weight of the ice was measured at the beginning of the experiment and when the temperature reached 10°C.



Fig. 4. The three shipping boxes studied.

RESULTS

Figure 5 illustrates the performance of the standard box, without insulating material, in an environmental temperature of 28°C. Note that the temperature of the blood had already reached the top of the so-called safety zone of 10°C by 10 hours. At that time, 7 pounds of ice, or half the original amount, were still present. Though the presence of ice has been used to indicate that the box was still at a safe temperature of 10°C or less, it is apparent that after 10 hours, despite the presence of ice, the temperature of the blood had exceeded the safe temperature. In addition, the box was re-iced and the temperature of the units was not reduced by the added 14 pounds of ice. The units remained at relatively the same temperature, and then continued to warm; thus, the ice did not actually cool the blood.

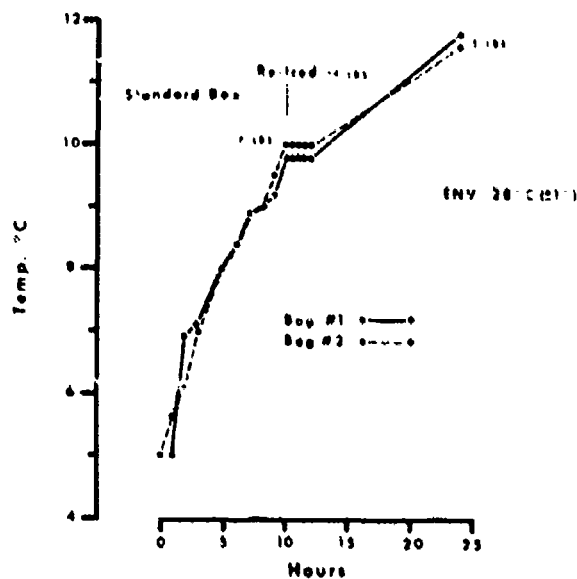


Fig. 5. Performance of the standard box in 28°C environment.

Figure 6 shows the advantage of additional insulation afforded by the insert at an environmental temperature of 30°C, and also the sharp difference in time required for each box to reach 10°C. Again, note that 9.5 pounds of ice in the standard box remained unmelted. Moreover, if the ratio of ice melting to temperature rise continued at the same rate, the temperature would soon be over 20°C and still contain unmelted ice.

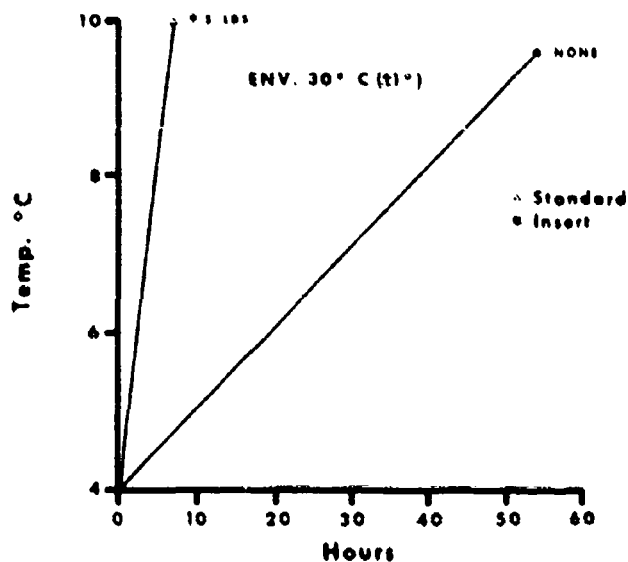


Fig. 6. Performance of the standard box with and without insert in 30°C environment.

In a tropic-like temperature of 38°C , with 80% relative humidity, the standard box protected the blood below 10°C for only 5 hours, while the insert and a heavier insulated box provided the same protection for 15 and 25 hours, respectively—a three- and fivefold advantage. A graphic comparison shown in Figure 7 clearly depicts this advantage.

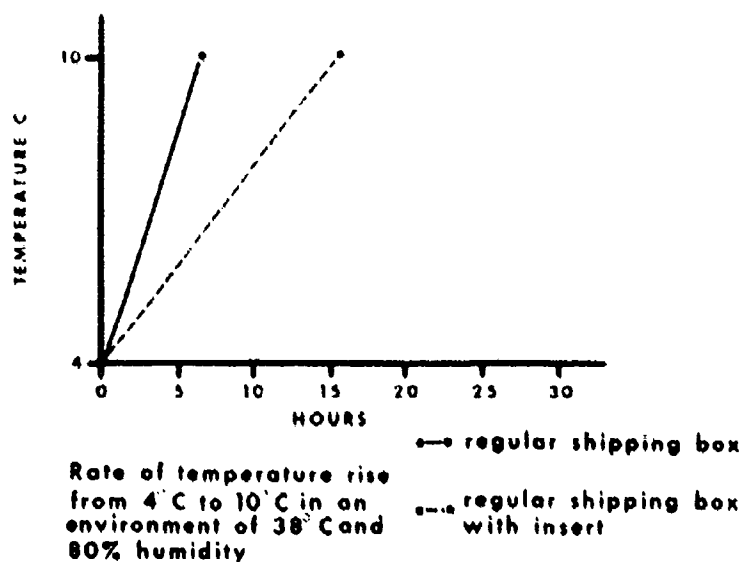


Fig. 7. Comparison of the regular shipping box with and without the insert and a heavier insulated box.

DISCUSSION

Though the instructions on the present standard box prescribe re-icing at least every 24 hours, or more often if external temperatures are over 33°C or 90°F , it is apparent that these guidelines may fail to maintain the units at a safe temperature. The relationship between temperature-holding capacity of each type of box and time shows that the standard cardboard box with insulating plastic insert is three times more effective than the uninsulated container. The findings of these temperature studies would indicate that the effects of external temperatures can best be modified by more effective insulation. Present military activities, requiring long distance shipment of blood, have a need for temperature protection, and the insertion of the plastic liner has provided an immediate answer as long as the external environmental temperatures remain relatively temperate.

The generalization often made that the presence of ice is satisfactory evidence as to the temperature of the box is clearly in error. The presence of unmelted ice cannot be considered a reliable sign of safe blood temperature. In addition, wet ice added to the container did not lower the temperature of the blood in these studies. Hence, in contrast to the monitoring of the blood bank refrigerator, which must be continuous to protect the blood from the effects of both warming and cooling, the temperature of the blood in the shipping box can only become warmer. Thus, it would seem practical and important to measure the temperature of the blood in the box because this temperature would represent the actual maximum temperature. A variety of methods exists for monitoring temperatures; however, simply placing a

thermometer inside the box or among the units would be a better estimate of the blood temperatures in the field than relying on the amount of unmelted ice. Other more sophisticated measures may become necessary to meet special needs involved in long distance shipping, though current air delivery methods, using inserts under controlled environmental temperatures, have been able to meet present overseas military needs.

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